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Automated Assessment and Visualisation of Measurement Uncertainties in a Low-Cost Marine Sensor Network

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In order to increase confidence in data collected automatically from real-time sensors and sensor networks, it is crucial that processes are put in place to also automatically assess the quality of the data and to estimate measurement uncertainty. The development of low-cost sensor nodes for environmental and industrial applications, which often feature sensors with reduced precision and accuracy, provide further impetus to the development of automated quality control techniques.

In a previous work we outlined a prototype framework for automated data quality control (QC), based not only on data statistics but also on the expert knowledge of domain specialists. It utilised fuzzy sets, which are an ideal way to encode and combine qualitative judgments, heuristic rules and knowledge. The framework was implemented and tested within the TasMAN marine sensor network in south-east Tasmania, Australia [1].

The components of uncertainty in a measurement can be grouped into two categories according to the way in which their numerical value is estimated [2]: those which are evaluated by statistical methods are classified as "Type A", and those which are evaluated by other means are classified as "Type B". Type B evaluation of standard uncertainty is based on scientific judgment using all of the relevant information available, which may include:
- previous measurement data,
- experience with, or general knowledge of, the behaviour and property of relevant materials and instruments,
- manufacturer's specifications,
- data provided in calibration and other reports, and uncertainties assigned to reference data taken from handbooks.

Finally, thresholds may be applied to identify measurement results that are not physically possible (e.g., a measured water temperature of -10 degrees C in the Ocean). Our fuzzy-based system takes Type A and Type B inputs and uses thresholds [1]. Type A inputs include, for example, the rate of change of sensor readings and comparison with similar nearby sensors. Type B inputs include the length of time that the sensor has been in the water and hence subject to biofouling, expert judgment on the quality of the sensor, and the time elapsed since the sensor was last calibrated.

The automated data QC system described in [1] has been expanded to output both data quality flags (in line with the International Oceanographic Data and Information Exchange [3]) and an interval estimate for each sensor reading.

A second key component of this work is the visualisation of uncertainty. Data from the TasMAN network can be obtained from a database or a web application [4]. The latter features an interactive map with node locations which can be selected to obtain the latest sensor reading, and a graphing function for examining historical data. Both of these data access mechanisms have been modified to also display uncertainty information.

Each sensor reading on the interactive map is now preceded by a coloured square indicating the quality of the reading. If this square is selected, further information is provided which outlines the reasons for the data quality assessment.

The graphing function allows the user to choose between no uncertainty information, error bars on data points, or confidence intervals around the entire data stream.

In this paper we will present both our revised approach to estimating uncertainty in data from our marine sensor network, and our approach to the visualisation of these data. We will highlight the advantages of this

approach, including in the re-purposing of data and in the scheduling of network maintenance.

References
[1] G.P. Timms, P.A. de Souza and L. Reznik, “Automated Assessment of Data Quality in Marine Sensor Networks”, presented at IEEE Oceans 2010, Sydney, Australia, 24-28 May 2010.
[2] ISO/IEC Guide 98:1995, “Guide to the expression of uncertainty in measurement”, International Organization for Standardization, Geneva, 1995, and references therein.
[3] See, for example, S. Mancini, K. Tattersall and R. Proctor, “IMOS NetCDF User’s Manual - NetCDF Conventions and Reference Tables”, Version 1.2 , April 30th, 2009.
[4] www.csiro.au/tasman/sensorweb